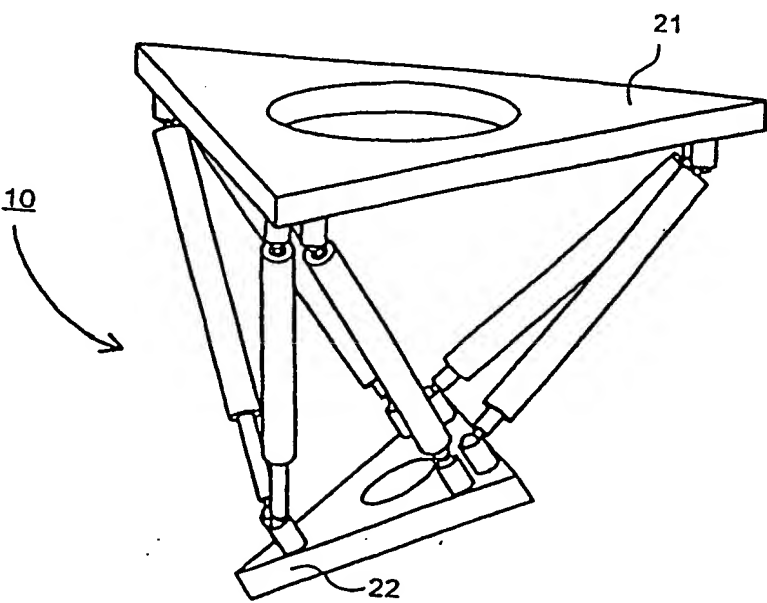




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : A61B 6/00, B25J 17/02, 9/10	A1	(11) International Publication Number: WO 99/30614 (43) International Publication Date: 24 June 1999 (24.06.99)
<p>(21) International Application Number: PCT/FI98/00968</p> <p>(22) International Filing Date: 11 December 1998 (11.12.98)</p> <p>(30) Priority Data: 974503 12 December 1997 (12.12.97) FI</p> <p>(71) Applicant (for all designated States except US): PLANMECA OY [FI/FI]; Asentajankatu 6, FIN-00810 Helsinki (FI).</p> <p>(72) Inventor; and (75) Inventor/Applicant (for US only): MÜLLER, Timo [FI/FI]; Tornihaukantie 6 A 20, FIN-02620 Espoo (FI).</p> <p>(74) Agent: FORSSÉNS &amp; SALOMAA OY; Yrjönkatu 30, FIN-00100 Helsinki (FI).</p>	<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments. In English translation (filed in Finnish).</p>	
(54) Title: ROBOT MANIPULATOR FOR MEDICAL IMAGING MEANS		
<p>(57) Abstract</p> <p>The invention relates to a medical imaging means including a movement mechanism (10). The movement mechanism (10) comprises a first mounting part (21) and a second mounting part (22) and at least three link arm members. The link arm assemblies of the mechanism include actuator means and a link arm member or a set of link arm members. The movement mechanism is used for moving a medical imaging device or a part thereof.</p> 		

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon	KR	Republic of Korea	PL	Poland		
CN	China	KZ	Kazakhstan	PT	Portugal		
CU	Cuba	LC	Saint Lucia	RO	Romania		
CZ	Czech Republic	LI	Liechtenstein	RU	Russian Federation		
DE	Germany	LK	Sri Lanka	SD	Sudan		
DK	Denmark	LR	Liberia	SE	Sweden		
EE	Estonia			SG	Singapore		

## Robot manipulator for medical imaging means

5

The present invention relates to a medical imaging means including a movement mechanism having a first mounting part and a second mounting part and at least three link arm assemblies, said link arm assemblies including actuator means and a link arm member or a set of link arm members, whereby said movement mechanism  
10 is used for moving a medical imaging device or a part thereof.

15

A great number of medical imaging methods require the movement of the imaging device or parts thereof. Such a movement can be orbital, rotational or linear. In conventional systems, the implementation of the movements requires extremely  
15 complicated arrangements.

20

The use of parallel-arm mechanisms is known from robotic systems for implementing a 3-dimensional movement. Such an arrangement has two essentially planar elements connected to each other by link arms or pairs of link arms of a controllable length. In the following text, such an arrangement is called a parallel-arm mechanism. One of the planar elements is fastened to a support structure, while the other planar element carries mounted thereon the means whose movement is desired. By adjusting the length of the link arms by active actuator means, a complete 3-dimensional freedom of movement is attained over spatial area needed for a  
25 specific task. Such a mechanism is commonly used in, e.g., machining equipment, aircraft simulators and placement of electronic components.

25

30

It is an object of the present invention to provide an improved medical imaging means and particularly an improved movement mechanism for use with the same.

It is a particular object of the present invention to provide an improved movement mechanism for use in conjunction with a panoramic radiography apparatus.

It is a still further particular object of the present invention to provide an improved movement mechanism for use in conjunction with a mammography apparatus.

To achieve the above-described goals and others to be mentioned later in the text,  
5 the invention is principally characterized in that

- a first mounting part is adapted mountable on a support structure such as a wall, ceiling or support beam,
- medical imaging device or a part thereof,
- 10 — link arm members are pivotally connected at pivot points to said first mounting part and said second mounting part,
- the length or position of said link arm members is adapted controllable by an actuator means, and
- the position, inclination and/or rotation of said second mounting part is  
15 adapted controllable by virtue of adjusting the length of the link arm members and/or the height of their pivot point.

In the invention, the above-mentioned parallel-arm mechanism has been adapted to a novel application, namely, for implementing the trajectory of dynamically moving  
20 members in medical imaging apparatuses. No movement mechanism of a medical imaging apparatus is known in the art to be constructed using this type of parallel-arm mechanism.

Medical imaging apparatuses pose extremely tight requirements on the accuracy of  
25 an arrangement implementing a trajectory. The use of a parallel-arm mechanism in such demanding applications as machining equipment has proved its capability of accomplishing an extremely precise and smooth trajectory.

The unlimited degree of freedom achievable by a parallel-arm mechanism in 3-  
30 dimensional dynamic movements over a desired area facilitates the implementation of all known imaging modes including fluoroscopy, 3D tomography, tomosynthesis imaging and slit fluoroscopy.

The use of a parallel-arm mechanism for implementing the trajectories required in a medical imaging apparatus is particularly advantageous owing to the simple construction of such a movement mechanism. Hence, the structure of the mechanism is more cost-efficient in production than conventional constructions and it is easily connectable to other parts of an imaging apparatus. The accuracy of the trajectory thus accomplished is excellent which is a significant benefit in medical imaging.

In the following, the invention is described in greater detail with reference to a preferred embodiment thereof having a nonlimiting character to the scope and spirit of the invention, said embodiment being illustrated in the appended drawings in which

Figure 1 shows a general view of a parallel-arm mechanism;

Figure 2 shows a parallel-arm mechanism connected to the C-arcuate body part used in a panoramic radiography apparatus;

Figure 3A shows the parallel-arm mechanism from below in its basic position;

Figure 3B shows the parallel-arm mechanism from below with its second mounting parts rotated;

Figure 3C shows the parallel-arm mechanism from below with its second mounting part rotated and moved;

Figure 3D shows the parallel-arm mechanism from below with its second mounting part moved into its first limit position;

Figure 3E shows the parallel-arm mechanism from below with its second mounting part moved into its second limit position;

Figure 4A shows the parallel-arm mechanism in a side view illustrating the situation of Fig. 3C;

Figure 4B shows the parallel-arm mechanism in a side view illustrating the situation  
5 of Fig. 3E;

Figure 5 shows the parallel-arm mechanism in a situation having one of its mounting parts inclined;

10 Figure 6 shows a side mounting of the parallel-arm mechanism;

Figure 7 shows a side mounting of the parallel-arm mechanism, now connected to a C-arcuate body part suited for use in a mammography application; and

15 Figure 8 shows an alternative mechanism for implementing a parallel-arm mechanism.

Now referring to Fig. 1, therein is shown a parallel-arm mechanism 10 in an upright position. There are mounted six link arm members between its first mounting part  
20 21 and its second mounting part 22. While in the illustrated embodiment, the first mounting part 21 and the second mounting part 22 have a triangular shape of essentially planar structure, also mounting parts of any alternative shape are possible in practice.

25 In the embodiment shown herein, each corner of each triangular mounting part 21, 22 has two connection points for the link arm members. To each triangular corner of the first mounting part 21, there are connected two link arm members having their other ends connected to separate connection points on the second mounting part 22. Either end of the link arm members 11,12,13,14,15,16 is provided with a ball joint  
30 N fixed on the mounting parts 21,22. To each link arm member 11,12,13,14,15,16 is adapted an actuator M capable of controlling the length of its dedicated link arm member. By controlling the lengths of the link arm members individually, it is

possible to implement a linear, rotational or tilting movement or a combination of these. The lengths of the link arm members are steered according to a predetermined control program.

- 5 In Fig. 2 is shown a parallel-arm mechanism 10 having its one mounting part carrying a body part 41 shaped as a C-arm. In this embodiment, the C-arm 41 is used in panoramic radiography for the imaging of the jaw bone and the teeth. For this application, the height position of the C-arm 41 and its position in the horizontal plane are controlled. The actual rotating movement required in panoramic radio-
- 10 graphy is accomplished with the help of an active actuator 18. The actuator M and the active actuator means 18 connected to the link arm members of the parallel-arm mechanism 10 are controlled by a microprocessor-based control system or using any other type of predetermined control program.
- 15 In Fig. 3A is shown the parallel-arm mechanism as seen from below in its basic position. In this position, all the link arm members are controlled equally long. The first mounting part 21 and the second mounting part 22 are then parallel and their center points fall on the same axis.
- 20 In Fig. 3B is shown the parallel-arm mechanism as seen from below with its second mounting part 22 rotated with respect to the basic position (cf. Fig. 3A). The rotational movement is implemented by controlling the lengths of the link arm members.
- 25 In Fig. 3C is shown the parallel-arm mechanism as seen from below with its second mounting part 22 rotated and moved away from the center axis of the first mounting part 21.
- 30 In Fig. 3D is shown the parallel-arm mechanism as seen from below with its second mounting part 22 moved into its first limit position. The link arm members 13 and 16 are controlled into their longest position. From this position, the center point of the second mounting part 22 cannot be moved farther away from the center point of

the first mounting part 21, but however the second mounting part 22 can still be rotated or inclined from said position by controlling the lengths of the link arm members.

- 5 In Fig. 3E is shown the parallel-arm mechanism as seen from below with its second mounting part 22 moved into its second limit position. Now the link arm members 11 and 16 are controlled into their longest positions.

10 In Fig. 4A is shown the situation of Fig. 3C in a side view. In this position, the first mounting part 21 and the second mounting part 22 are situated parallel to each other.

In Fig. 4B is shown the situation of Fig. 3E in a side view.

- 15 In Fig. 5 is shown the parallel-arm mechanism 10 in a position having the second mounting part 22 controlled into an inclined position.

20 In Fig. 6 is shown a side mounting of the parallel-arm mechanism 10. Herein, the first mounting part 21 is now oriented upright thus permitting its fastening on, e.g., a wall, support beam or a part of a medical imaging apparatus. The movable part of the imaging apparatus is mounted on the second mounting part 22.

- 25 In Fig. 7 is shown a side mounting of the parallel-arm mechanism, now connected to a C-arcuate body part 42 which in this embodiment is suited for use in a mammography application. This kind of movement mechanism according to the invention offers a greater number of degrees of freedom than conventional constructions of mammography equipment. To the C-arcuate body part 42 of a mammography apparatus is connected an active actuator means 19 in order to provide a rotating movement. The actuators M and the active actuator means 19 that are connected to the link arm members of the parallel arm mechanism 10 are controlled  
30 by a microprocessor-based control system or using any other type of predetermined control program.



- In Fig. 8 is shown an alternative mechanism for implementing a parallel-arm mechanism. Herein, the first mounting part comprises an upper support plate 51 with actuator motors M and a support ring 52 connected thereto, and threaded control link arms S connecting said support ring 52 to said upper support plate 51. Actuator-driven nuts N are adapted to run on the threaded control link arms S. Between the actuator nuts N and the second mounting part 22, there are disposed stiff link arm members 61,62,63,64,65,66, each of which having their first end pivotally connected to the actuator nut N running on the threaded control link arm S and their other end similarly pivotally connected to said second mounting part 22. Each actuator motor M is adapted to rotate the threaded control link arm S connected to the motor output. With the rotation of the threaded control link arm S, the position of the nut N running on the arm can be changed thus imparting a linear motion on the link arm member 61,62,63,64,65 or 66 which is respectively connected to the nut. Thus, the controlled movement of the connection points of the link arm members on the first mounting part implements the controlled steering of the position, rotation and inclination of the second mounting part 22. The actuators M are controlled by a microprocessor-based control system or using any other type of predetermined control program.
- In Figs. 1—8 are shown the positions of the parallel-arm mechanism members in different stationary positions. Typically, a parallel-arm mechanism is used to accomplish a continuous dynamic movement, and the purpose of the above-described examples is to elucidate the instantaneous positions of the parallel-arm mechanism during its dynamic movement.
- According to the needs of any specific application, the above-described movement mechanism may be modified in a plurality of different fashions within the scope and spirit of the invention. For instance, the first mounting part 21 and the second mounting part 22 may be designed into the shape of any feasible and practicable structure. The first mounting part 21 of the parallel-arm mechanism may alternatively be fastened to the ceiling of the radiography room or to a separate support beam or other part of the imaging apparatus.

The scope of the invention is defined in the appended claims.

## Claims

1. Medical imaging means comprising a movement mechanism having a first mounting part (21) and a second mounting part (22) and at least three link arm assemblies (12,14,16) that include actuator means (M) and a link arm member or a set of link arm members, said movement mechanism being used for moving a medical imaging device or a part thereof, characterized in that
- said first mounting part (21) is adapted mountable on a support structure such as a wall, ceiling or support beam,
  - said second mounting part (22) is adapted connectable to a medical imaging device or a part thereof,
  - said link arm members are pivotally connected at pivot points to said first mounting part (21) and said second mounting part (22),
  - the length or position of said link arm members is adapted controllable by an actuator means (M), and
  - the position, inclination and/or rotation of said second mounting part (22) is adapted controllable by virtue of adjusting the length of the link arm members and/or the height of their pivot points.
2. Imaging means according to claim 1, characterized in that the trajectory of said second mounting part (22) is steered by a control system based on a microprocessor and a computer program.
3. Imaging means according to claim 1 or 2, characterized in that said actuator means (M) is a hydraulic cylinder.
4. Imaging means according to claim 1 or 2, characterized in that said actuator means (M) is a linear motor.

5. Imaging means according to any of claims 1—4, characterized in that to said second mounting part (22) are adapted such means that are required for imaging with the help of a medical imaging device.
- 5 6. Imaging means according to any of claims 1—5, characterized in that to said second mounting part (22) is adapted an active actuator means (18) which rotates the imaging means of the medical imaging device.
- 10 7. Imaging means according to any of claims 1—6, characterized in that to said second mounting part (22) is adapted a C-arcuate body part (41) of a panoramic imaging apparatus having one end of the arcuate body part carrying a source of radiation and the other end carrying a detector of said radiation.
- 15 8. Imaging means according to any of claims 1—7, characterized in that to said second mounting part (22) is adapted an active actuator means (18) capable of rotating said C-arcuate body part (41) of said panoramic imaging apparatus.
- 20 9. Imaging means according to any of claims 1—8, characterized in that to said second mounting part (22) is adapted a C-arcuate body part (42) of a mammography apparatus.
10. Imaging means according to any of claims 1—9, characterized in that to said second mounting part (22) is adapted an active actuator means (19) capable of rotating said C-arcuate body part (42) of said mammography apparatus.

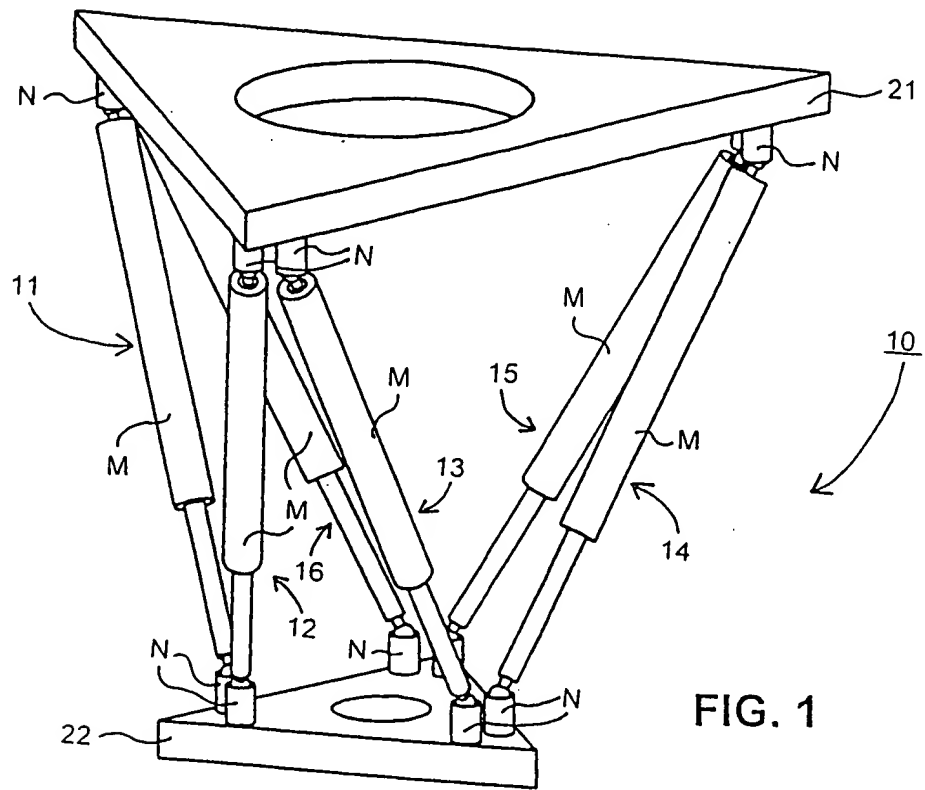


FIG. 1

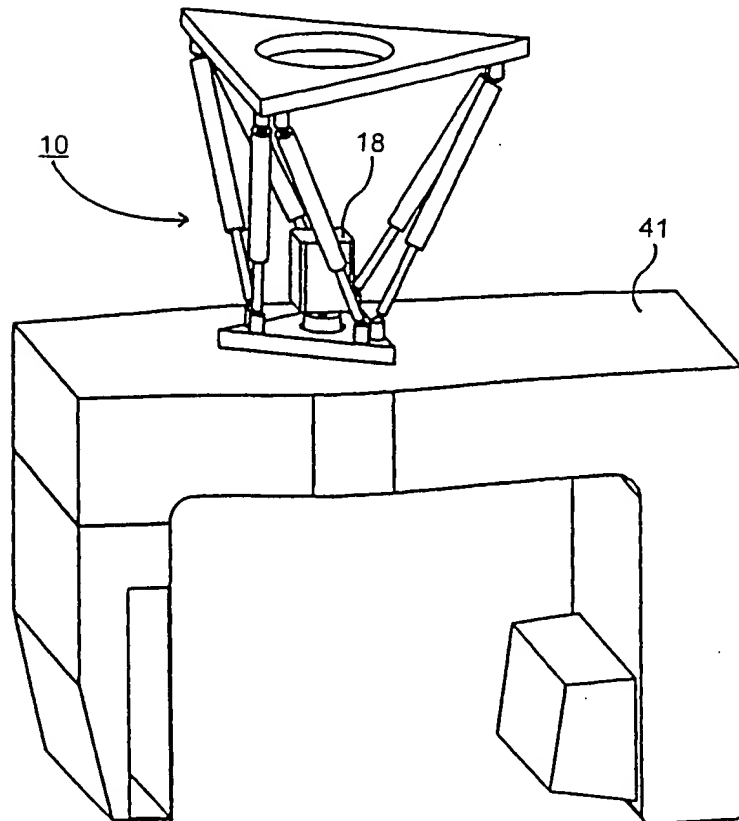


FIG. 2

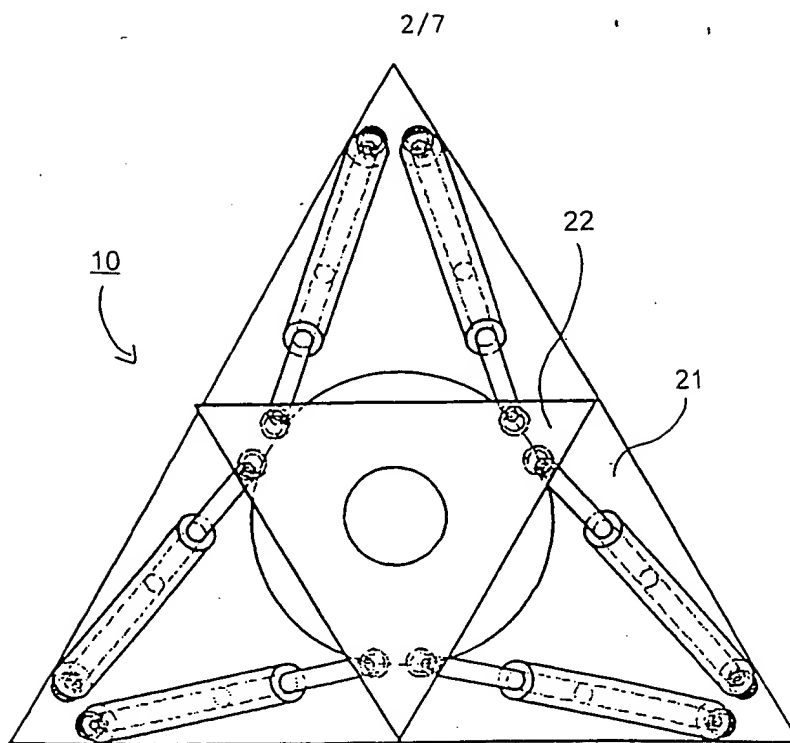


FIG. 3A

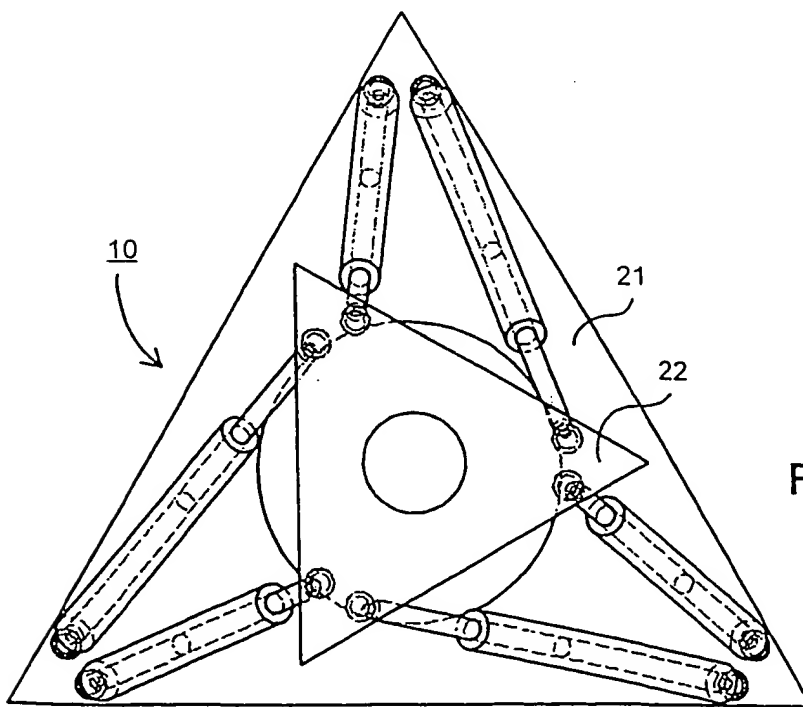


FIG. 3B

3/7

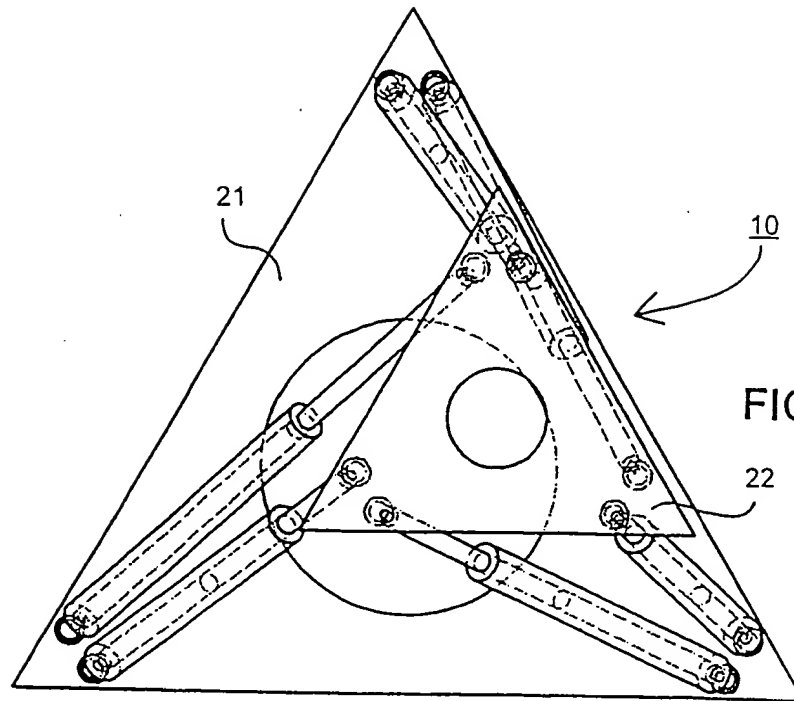


FIG. 3C

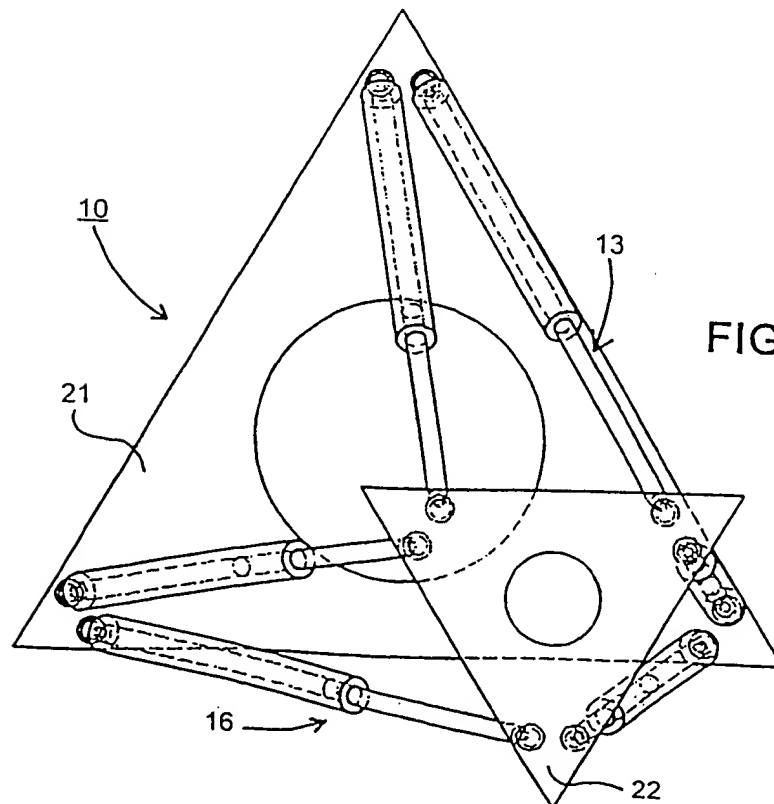
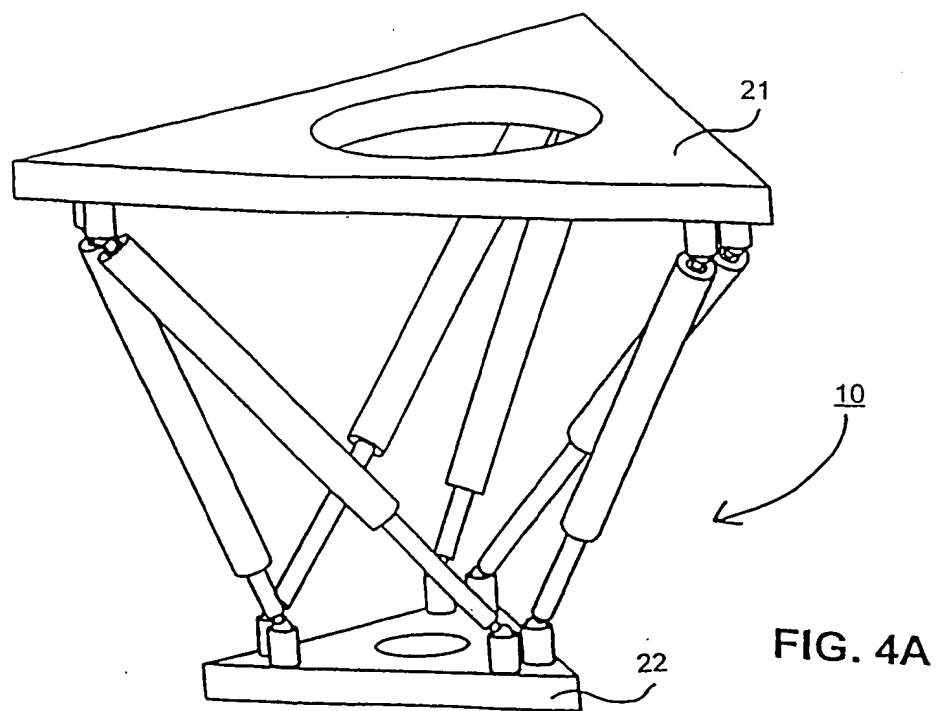
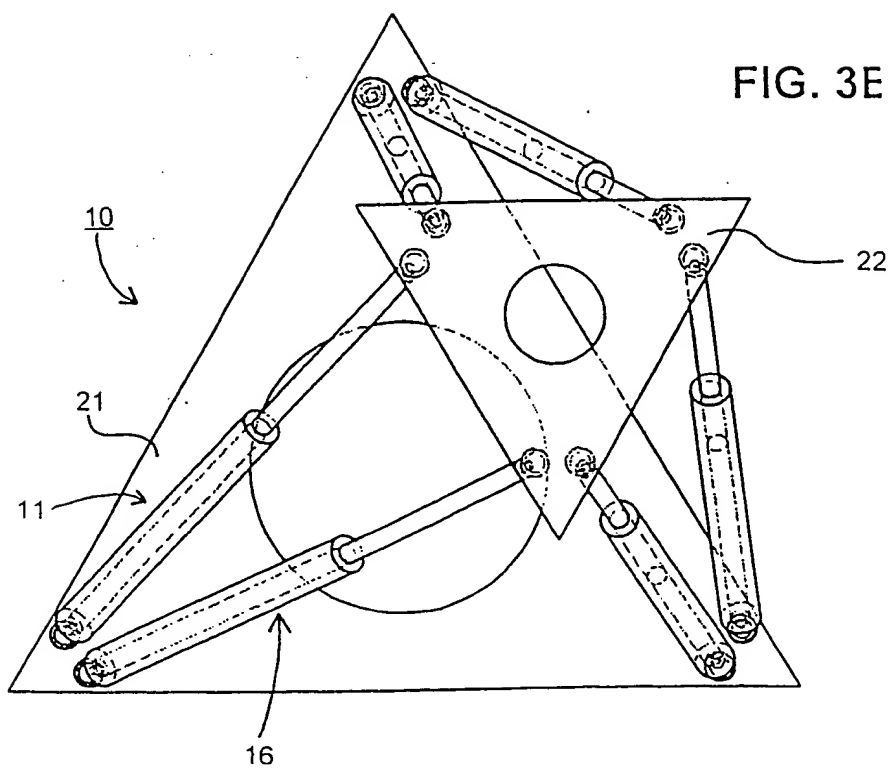
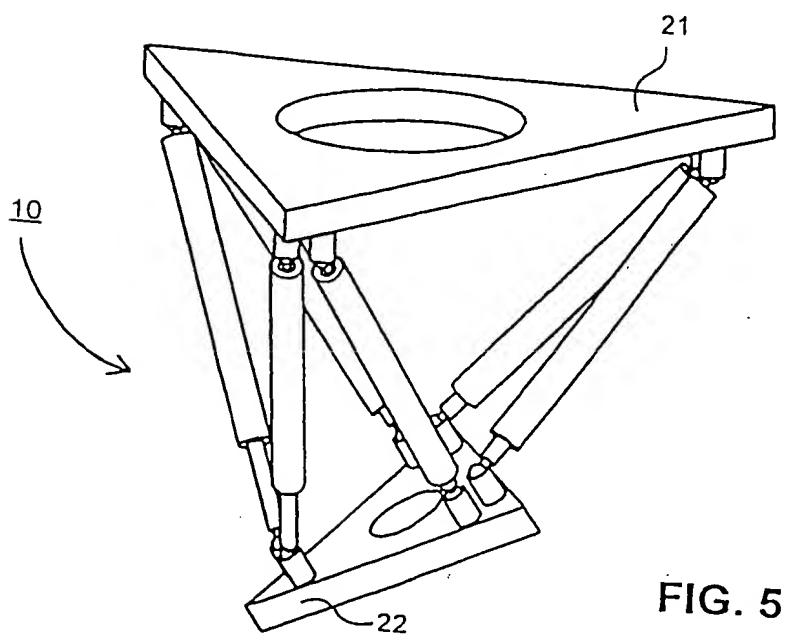
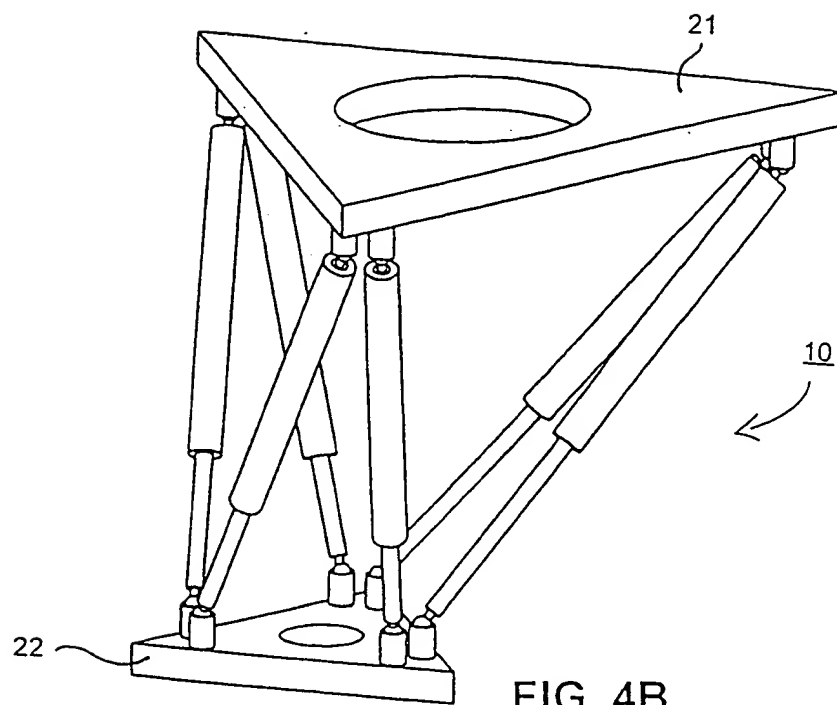


FIG. 3D







6/7

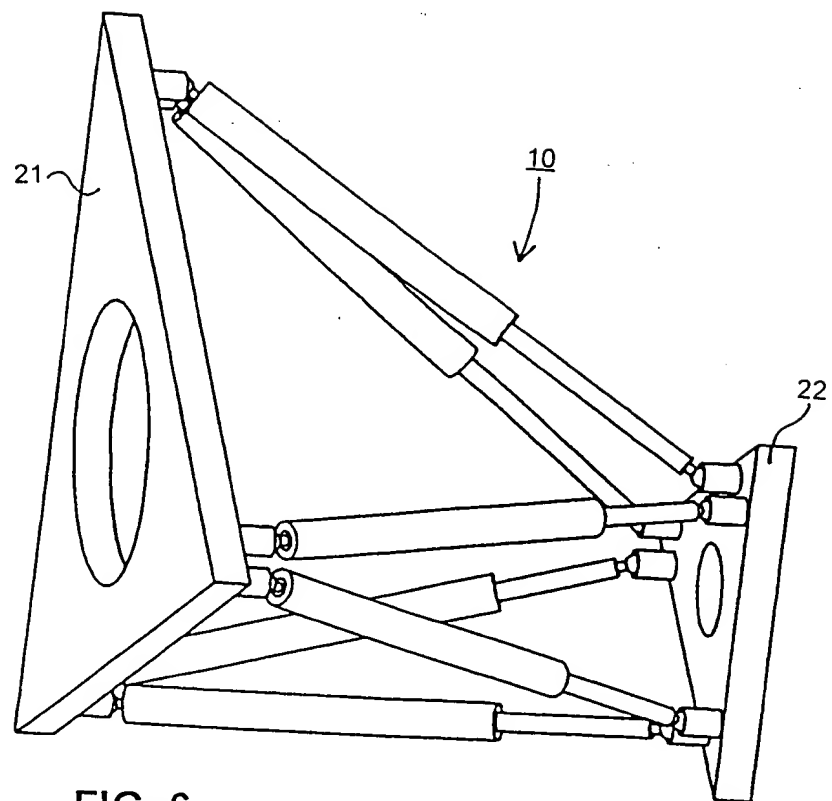


FIG. 6

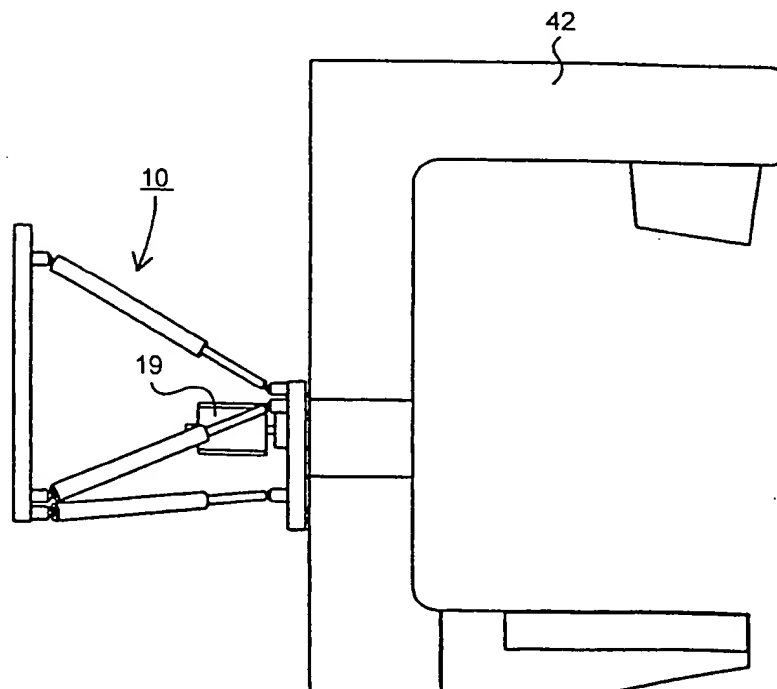


FIG. 7

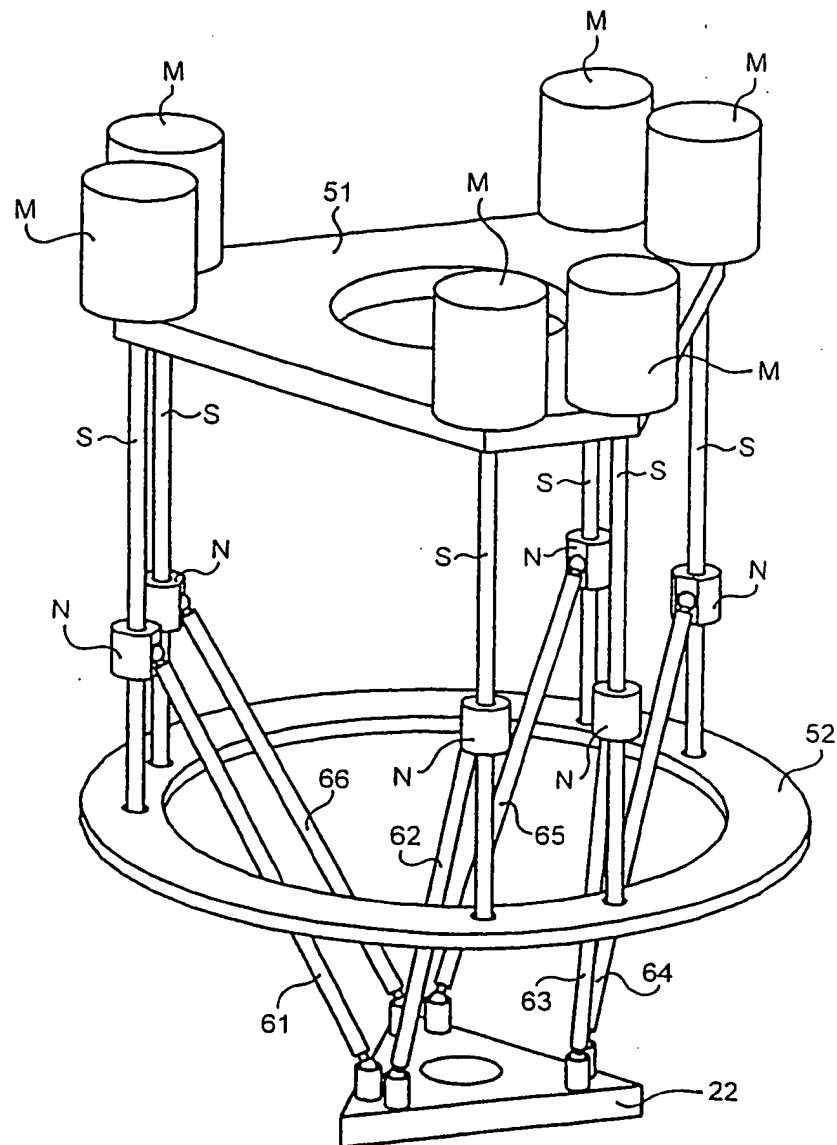


FIG. 8

